The Effects of Additives on the Quality and Nutritive Value of Packed Silage

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The losses during ensiling process are due to the action of respiration, fermentation, surface spoilage and seepage of the mass. As to the fermentation, LANGSTON et al.⁶⁾ showed that during the early stages of fermentation a degree of aeration of forage markedly influenced the bacterial flora and the chemical quality of the silage examined. Moreover, by WIERINGA et al.⁹⁾, it was proved that the grass under anaerobic conditions gave a silage of good quality, but an aeration and a high temperature (above 40°C) in the silage ensiling material caused a fixation of protein, a decrease in lactic acid formation and an increase in production of unfavorable ammonia, butyric or acetic acid.

Several workers proved that the quality of silage made with additives was much better than that of the conventional silage. Recently, the various additives such as acids, carbohydrates and antiseptic agents were widely used for the purpose of stimulating the development of desirable bacteria or checking the growth of putrefactive organisms.

As a conserving container, tower silo is ordinarily used but it is recognized that the losses in dry matter and nutritive value of the silage sometimes increases to a considerable extent by fermentation, spoilage and seepage.

It is considered that applying polyethylene film bags for ensiling forage materials can serve to make condition of fermentation more anaerobic, and some wilting of very succulent forages before ensiling is not needed by adding of absorbent agent such as starch. Moreover, the packed silage may be more convenient to handle and to feed than ordinary silage.

The present investigation was undertaken to clarify the effects of polyethylene film bags used as a container and of various additives on the quality and on the nutritive value of silages.

Materials and Methods

Packed silage preparation

This paper describes three trials to investigate the changes on the quality of silages prepared from three different kinds of materials and of different treatments, as are shown in Table 1.

In this experiment bags of polyethylene film (0.06 mm thick, 10 cm in diam. × 30 cm high in trial 1 and 2; 0.08 mm thick, 30 cm in diam. × 60 cm high in trial 3) were used for packing

Table 1. Treatment of each trial

Trial	Forage material	Date of cutting	Stage of growth	Treatment	Used level (%)	Weight of each packed forage (kg)	Pasteurization		Preservation	
							Water temp. (°C)	Time (mins.)	Temp. (°C)	Days
1 ¹⁾	Milk vetch	May 24	Early bloom	None	—	1	70~80	30	Incubate at 25	24
				Formalin	0.20					
				Vitamin K ₃	0.003					
				Salicylic acid	0.02					
				Butyl-p-oxybenzoic acid	0.01					
				Furazolidone	0.002					
				Na-dehydroacetic acid	0.02					
2 ²⁾	Ladino clover	July 13	Full bloom	Na-benzoate	0.06	1	70~80	30	Left alone at the room temp. (max. 30.5 min. 20.5)	21
				None	—					
				Formalin	0.20					
				Furazolidone	0.002					
3	Sweet potato vines	Oct. 1	Harvest time	Na-metabisulfite	0.30	25			Left alone at the room temp. (max. 18.5 min. 4.0)	29
				None	—					
				Penicillin	0.00001					
				Streptomycin	0.00001					
				Chloromycetin	0.00001					
				Achromycin	0.00001					

1) Corn starch was added at the level of 33.3% for each treatment.

2) Potato starch was added at the level of 25.0% for each treatment.

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materials to keep the anaerobic conditions of packed materials. In trial 1, corn starch was added at the level of 33.3 percent, and in trial 2, potato starch was added at the level of 25.0 percent for each treatment respectively, but in trial 3 starch was not used. The additives were added to green stuffs to preserve its qualities or to control acid fermentation. The level of these additives used was determined within the allowance of the food sanitary control except formalin, furazolidone and antibiotics. Formalin was applied on the low level of 0.2 percent, because it can be highly toxic even in small amounts. Furazolidone was used at the level of prophylactic dose, and the used dose of antibiotics was also on the normal level. The stuffed bags were tied fast with the linen thread, and then the packed forages were pasteurized in hot water before conservation in order to regulate the bacterial and enzymatic action during the early stages of fermentation. The process of packing and preserving forages was as follows.

Packing Process of Forage

Green forage material → Chopping and bruising → Mixing with additives (starch, antiseptics or antibiotics) → Stirring → Packing in bags → Sealing with thread → Pasteurization (70~80°C, 30 min.) → Conservation.

Chemical analyses

Chemical analysis were accomplished as follows: a) Ten g samples of silage were macerated in a WARING blender for 10 minutes with about 50 ml distilled water, and the transparent solutions were then filled up at 250 ml after centrifugation. b) Dry matter of the silage was determined after drying in an oven at 105°C for about three hours. c) The pH was determined by the Hitachi pH meter M-3. d) Total and steamed volatile fatty acids were determined by titration¹⁾. Amount of non-volatile fatty acids was calculated by the deduction of volatile fatty acids from total acids, and volatile fatty acid was represented as acetic acid and non-volatile fatty acid was represented as lactic acid. e) Total nitrogen was determined by the KJELDAHL method²⁾ and ammonia nitrogen was determined by the diffusion method of CONWAY³⁾. Amino nitrogen was determined by the VAN SLYKE manometric method¹⁾.

Digestion trials

In order to compare the digestibility and protein utilization of the packed silage, 12 male rabbits of about 2 kilograms of body weight were allocated at random to 6 treatments as

Table 2. The silage samples used in digestion trials

Trial	Silage samples treated with additives
1	None Formalin Furazolidone Na-metabisulfite
2	None Streptomycin

The silage samples in trial 1 and 2 are the same ones that were used in trial 2 and 3 at Table 1 respectively.

shown in Table 2. All rabbits were kept in the individual metabolism cages throughout the experimental period. The silage samples in each treatment were stored in freezing box until they were used in feeding. After 10 days' preliminary feeding of the respective silage samples from each treatment, silage, feces and urine samples were weighed and measured daily for 7 days. In each treatment of trial 1, the silage was fed once daily. And in trial 2, 13 percent of wheat bran was added to the silage samples of each treatment, so the data of the digestibility, T.D.N. and biological value⁷⁾ of protein in trial 2 indicate the values of the combined diet of packed silage plus wheat bran.

Results and Discussion

It is well recognized that in most cases, the high moisture content of the herbage material tends to decrease the quality and nutritive value of the products. In order to reduce the high moisture content in such succulent herbage, starch was used as an absorbent agent in this experiment. Moreover, by bruising and stuffing with chopper, macerated forages were compactly put into the bags. Thus, it is evident that the starch serves as an energy source for the animal, besides it fills up the mass and serves also as a food for microflora.

A subjective evaluation of silage in appearance and odour was fairly high. Average dry matter and organic acids content and also pH value of the silages are shown in Table 3.

In trial 1, the addition of various conservatives except formalin and furazolidone had little

Table 3. The pH, dry matter and organic acid concentration of packed silages

Trial	Treatment	pH	D.M. (%)	Percent on dry matter basis		
				Total acids	Steamed volatile acids	Non- volatile acids
1	None	5.00	36.8	0.54(100)	0.31(57.4)	0.23(42.6)
	Formalin	5.94	36.1	0.14(100)	0.07(50.0)	0.07(50.0)
	Vitamin K ₃	4.78	35.1	0.85(100)	0.69(81.2)	0.16(18.8)
	Salicylic acid	5.07	35.5	0.51(100)	0.32(62.7)	0.19(37.3)
	Butyl-p-oxybenzoic acid	4.61	32.1	1.21(100)	0.98(81.0)	0.23(19.0)
	Furazolidone	6.01	33.7	0.09(100)	0.09(100.0)	— (0.0)
	No-dehydroacetic acid	4.87	33.1	0.97(100)	0.95(97.9)	0.02(2.1)
	No-benzoate	4.95	38.1	0.58(100)	0.37(63.8)	0.21(36.2)
2	None	4.16	36.3	2.89(100)	1.72(59.5)	1.17(40.5)
	Formalin	4.20	38.8	1.65(100)	0.65(39.4)	1.00(60.6)
	Furazolidone	4.20	32.8	2.65(100)	0.86(32.5)	1.79(67.5)
	Na-metabisulfite	4.60	37.2	1.85(100)	0.56(30.3)	1.29(69.7)
3	None	3.87	14.5	5.86(100)	1.20(20.5)	4.66(79.5)
	Penicillin	4.01	9.1	7.47(100)	2.20(29.5)	5.27(70.5)
	Streptomycin	4.01	11.3	5.84(100)	1.97(33.7)	3.87(66.3)
	Chloromycetin	4.00	12.0	6.67(100)	1.83(24.4)	4.84(75.6)
	Achromycin	3.88	11.3	8.23(100)	1.84(22.4)	6.39(77.6)

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effect on pH and on the total acids. On the other hand, treatments with formalin and furozolidone considerably reduced the acid production. The results showed that both additives had a sterilizing property for the bacterial flora of the silages. From the results mentioned above, the 2nd trial has been conducted for the purpose of testing again the effects of formalin and furazolidone on the silage fermentations. In addition, the effect of well-known sodium metabisulfite was tested, too.

The pH value in the mass is usually influenced by organic acids and ammonia nitrogen. In trial 2, pH value of the mass added sodium metabisulfite was slightly higher than that of the other three groups.

Table 4. Nitrogen distribution in water soluble part of the packed silages

Trial	Treatment	In water soluble part				
		Total nitrogen	Amino nitrogen		Ammonia nitrogen	
		as % of D.M.	as % of D.M.	as % of T.N.	as % of D.M.	as % of T.N.
1	None	0.730	0.242	33.2	0.0432	5.91
	Formalin	0.679	0.313	46.1	0.0440	6.48
	Vitamin K ₃	0.744	0.436	58.6	0.0509	6.84
	Salicylic acid	0.634	0.223	35.2	0.0389	6.14
	Butyl-p-oxybenzoic acid	0.729	0.231	31.7	0.0707	9.70
	Furazolidone	0.674	0.320	47.5	0.0368	5.46
	Na-dehydroacetic acid	0.701	0.284	40.5	0.0583	8.32
	Na-benzoate	0.727	0.415	57.1	0.0488	6.71
2	None	1.683	0.435	25.8	0.0950	5.64
	Formalin	1.464	0.611	41.7	0.0889	6.07
	Furazolidone	2.021	0.421	20.8	0.1155	5.71
	Na-metabisulfite	1.724	0.384	22.0	0.1761	10.08
3	None	3.055	0.579	19.0	0.0669	2.19
	Penicillin	3.406	1.956	57.4	0.1670	4.90
	Streptomycin	3.026	1.088	36.0	0.1035	3.42
	Chloromycetin	3.250	1.358	41.8	0.1666	5.13
	Achromycin	3.071	0.832	27.1	0.1221	3.97

From the figures in Table 3 and 4, it is observed that the pH value of the silages was more strongly affected by ammonia nitrogen than by organic acids. In comparing trial 1 and 2, it is interesting that the acid production was not only influenced by the environmental temperature of the silages but also by the seasonal difference of the kind of bacteria and by the difference of the kind of forages. Acid producing bacteria were more developed in the temperature ranging from 20.5 to 30.5°C in warmer season than in the case of the constant temperature of 25°C in the cool season. In trial 3, the pH values were also quite similar in all treatments, but the acid production level was several times as high as the level in trial 1 or 2. In particular, non-volatile acid production in trial 3 has remarkably developed. The data indicate that the advance in controlling the acid production in trial 1 or 2 can be

attributed to the hot-water pasteurization. In trial 1, the content of total acids in the silage treated with butyl-p-oxybenzoic acid was very high, but whether this high value is attributable to the action of butyl-p-oxybenzoic acid or to any other factors, the reason could not be clarified. According to the work on the microbial flora of the silages by OCHI et al.⁸⁾, the addition of bacitracin had little effects on the microbial changes. And in the experiments of this paper on the acid production, the use of antibiotics (penicillin, streptomycin, chloromycetin and achromycin) has little effect on the fermentation process of silages.

Results of the digestion trials are shown in Table 5, 6, and 7. From the data it was found that the addition of sodium metabisulfite did not interfere with the digestibility and the protein utilization of packed silages, but the addition of both formalin and furazolidone depreciated materially the digestibilities of all nutrients. And the addition of streptomycin also reduced the total digestible nutrients of silages. In consideration of these results, it may be concluded that the above-stated disturbances in digestion have occurred, because of unfavourable denaturation of the protein and other nutrients by formalin addition on the one side, and because of inhibition of microbial function by furazolidone and streptomycin addition on the other side. But, in general, the data of apparent digestibility of protein in this survey were similar or relatively high in comparison with the data of LANDIS⁵⁾ and also with the data on wether lambs by HIDIROGLOU et al.⁴⁾. It is, therefore, that the anaerobic heating at high

Table 5. Chemical composition of packed silages and wheat bran (%)

Trial	Treatment	Moisture	Crude protein	Crude fat	Crude fiber	Crude ash	N.F.E.
1	None	63.70	3.81	1.00	3.07	2.05	26.37
	Formalin	61.50	4.15	1.08	3.27	2.12	27.88
	Furazolidone	67.21	3.55	0.89	2.84	1.83	23.68
	Na-metabisulfite	62.80	4.06	1.04	2.95	2.13	27.02
2	None	85.61	2.75	0.32	3.07	2.05	6.20
	Streptomycin	88.60	2.14	0.31	2.91	1.44	4.60
	Wheat bran ¹⁾	14.67	16.63	2.00	10.00	4.90	51.80

1) 13 percent of wheat bran was supplemented to the packed silage of each treatment in trial 2.

Table 6. Apparent digestibility of some nutrients and T.D.N. of packed silages (%)

Trial	Treatment	Apparent digestibility					T.D.N.
		Crude protein	Crude fat	Crude fiber	Crude ash	N.F.E.	
1	None	67.2	74.4	60.6	69.3	83.4	77.5
	Formalin	62.5	48.9	40.1	67.7	72.4	65.6
	Furazolidone	64.3	52.1	19.7	62.9	66.5	63.3
	Na-metabisulfite	69.0	68.3	37.8	70.7	84.6	76.2
2	None	64.7	43.2	-2.9	48.2	51.1	40.4
	Streptomycin	60.2	63.8	2.6	27.0	43.5	37.7

The data are indicated on the average of two rabbits.

Table 7. Calculation of biological value, true digestibility and nitrogen retention of packed silages

Trial	Treatment	Body weight (g)		Feed consumed per day (g)	Excreted per day		Intaked nitrogen (g)	Fecal nitrogen (g)	M.F.N. ¹⁾ (g)	Urinary nitrogen (g)	E.U.N. ²⁾ (g)	Biological value of protein (%)	True digestibility (%)	Nitrogen retained per day (g)
		Initial	Final		Feces (g)	Urine (g)								
1	None	2,448	2,395	225	18.4	104.5	1.369	0.446	0.065	0.658	0.311	65.6	72.5	0.265
	Formalin	2,333	2,340	227	33.0	107.1	1.508	0.563	0.071	0.647	0.304	68.9	72.9	0.298
	Furazolidone	2,070	2,093	213	29.0	110.9	1.207	0.457	0.056	0.582	0.272	62.0	66.6	0.169
	Na-metabisulfite	2,323	2,375	247	20.9	138.3	1.603	0.492	0.074	0.512	0.309	83.2	73.5	0.599
2	None	1,723	1,760	329	45.6	206.0	2.398	0.849	0.039	1.101	0.229	44.2	66.4	0.449
	Streptomycin	1,905	1,915	322	44.1	205.0	2.069	0.831	0.029	1.414	0.249	8.4	61.6	-0.175

The data are indicated on the average of two rabbits.

1) Metabolic fecal nitrogen : 0.080 g/100 g of dry matter of the feed

2) Endogenous urinary nitrogen: 0.130 g/1 kg of body weight

temperature for short time sterilization preceding to the preservation did not reduce the protein digestibility.

In Table 7, it can be seen that the biological values of silage samples have varied in proportion to the nitrogen retained. Especially, in the case of sodium metabisulfite treatment both the biological value and the nitrogen retention were very high, but the reason for this high level was not clarified. And, it is also unknown that whether the depression of the biological value of streptomycin treatment is due to the condition of animal disorder or to any other factors.

Summary

Three trials were conducted to investigate the effects of additives on the quality and nutritive value of packed silage.

Among various additives, formalin, furazolidone and sodium metabisulfite were effective to a certain extent for the control of silage fermentation. From the results of digestion trial, however, it was found that the addition of sodium metabisulfite did not interfere with the digestibility and protein utilization of packed silages, but the addition of both formalin and furazolidone depreciated materially the digestibilities of all nutrients. Moreover, it appears that the use of antibiotics (penicillin, streptomycin, chloromycetin and achromycin) has little effect on the fermentation process of the silage.

The results reported above suggest the short time anaerobic heating at high temperature for pasteurization preceding to the preservation did not reduce the protein digestibility, but depressed the acid production of packed silages.

The polyethylene film bag as a container was successfully used to maintain the anaerobic condition during fermentation process.

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包装サイレージの品質ならびに栄養価値におよぼす 添加剤の効果について

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種々の添加剤がサイレージの品質ならびにその栄養価値におよぼす影響を調査する目的で本実験を行なった。

まず、磨砕した緑飼料に水分調整とカロリー源の補給を目的として、これに生草重の1/3程度のデンプンを加え(試験の一部にはデンプンを使用せず)、さらに各種の添加剤を添加混合した上でポリエチレン袋(詰込容量1 kg と 25 kg の2種)に固く詰め、結紮後そのままの状態、あるいはまた加熱殺菌(70~80°Cの熱水中にて約30分間)処理をほどこした上で3~4週間室温または恒温(25°C)にて貯蔵した。

これらの製品のpH、有機酸含量、アミノ態窒素ならびにアンモニア態窒素含量をそれぞれ測定するとともに、製品の一部については家兎による消化試験ならびに窒素の出納試験を行ない、その栄養価値を比較検討した。その結果はつぎの通りである。

種々の添加剤の中でホルマリン、フラゾリドンおよびピロ亜硫酸ナトリウムは、サイレージの醗酵を抑制するのにかなりの効果があつた。しかしながら動物試験の結果からは、ホルマリンならびにフラゾリドンの添加により製品の各成分の消化率ならびに蛋白質の利用性が著しく低下することが明らかとなつた。一方ピロ亜硫酸ナトリウム添加の場合においてはそのような悪影響は全くみられなかつた。なお抗生物質添加の場合もサイレージの醗酵にはほとんど影響をおよぼさないことが推察された。

また貯蔵前の加熱処理により有機酸の生成はかなり抑制されたが、蛋白質の消化率にはそれほどの影響はなかつた。

ポリエチレン袋による貯蔵は嫌気性保持の上から効果的であるように思われた。